

CEMENT FLOW CONTROL TOOL

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2

3 The present invention relates to a cement flow
4 control tool and especially but not exclusively, a
5 cement flow control tool for use in cementing a
6 string of tubulars such as a casing or liner string
7 into an oil, gas or water borehole.

8

9 Primary cementing is the process of placing cement
10 in the annulus between a casing or liner string and
11 the formations exposed to the borehole. A major
12 objective of primary cementing is to provide zonal
13 isolation in the borehole of oil, gas, and water
14 wells, i.e. to exclude fluids such as water or gas
15 in one zone from oil in another zone. To achieve
16 this, a hydraulic seal must be obtained between the
17 casing and the cement, and between the cement and
18 the formations, while at the same time preventing
19 fluid channels in the cement sheath. Without
20 complete zonal isolation, the well may never reach
21 its full producing potential and remedial work to

1 repair a faulty cementing job may do irreparable
2 harm to the producing formation. In consequence,
3 reserves may be lost and commencement of production
4 may be delayed.

5

6 After drilling the well to the desired depth, the
7 drillpipe is removed and a casing string is run in
8 until it reaches the bottom of the borehole. The
9 casing string typically has a shoe, such as a float
10 shoe, guide shoe or a reamer shoe on the end to
11 guide the casing string into the borehole. At this
12 time, the drilling mud (used to remove formation
13 cuttings during the drilling of the well) is still
14 in the borehole; this mud must be removed and
15 replaced by hardened cement.

16

17 This is done by passing cement down through the
18 inside of the casing string; the cement passes out
19 of apertures in the shoe and into the annulus
20 between the borehole and the casing. The drilling
21 mud is displaced upwards and the cement replaces it
22 in the annulus. The cement needs to extend at least
23 as far up the annulus so as to span the production
24 zones, and the previous casing shoe if present, and
25 sometimes the cement even extends to the surface.

26

27 However, the cement is heavy and so exerts a large
28 force on the drilling mud. Drilling mud is less
29 heavy than cement, so the cement causes the drilling
30 mud to travel quickly up the annulus. Fast flowing
31 drilling mud brings a high pressure to bear upon the
32 formation and excess solids and drill cuttings may

1 build up in the annulus, exerting even more pressure
2 on the formation. The formation may break down
3 under the pressure, resulting in both severe mud
4 loss and also a loss of production. Open hole
5 sections of the formation are especially prone to
6 collapse, possibly ruining the borehole.

7
8 An additional problem is that the cement, being
9 heavier, may also fall down through the drilling
10 mud, resulting in a poor cement job.

11
12 According to the present invention there is provided
13 apparatus for controlling the flow of cement into a
14 borehole through a conduit, the apparatus comprising
15 a decelerating means adapted to be positioned within
16 the conduit for slowing down the flow of fluid
17 through the conduit.

18
19 The deceleration means typically controls or
20 mitigates the free fall effect of the cement.

21
22 Preferably, the conduit is a drillpipe, tubing,
23 coiled tubing, filtration screen, casing or liner
24 string, but may be any conduit which is inserted
25 into a borehole.

26
27 Typically, the decelerating means comprises a
28 passage, and most preferably, the passage is defined
29 by at least one body member having formations
30 thereon.

31

1 Typically, the passage is inclined relative to the
2 axis of the conduit and deceleration of the fluid is
3 caused by friction between the fluid and the
4 inclined passage. Typically, the passage is also
5 inclined relative to a plane perpendicular to the
6 axis of the conduit. Optionally, the inclination of
7 the passage is continual throughout its length.

8
9 Typically, the inclined passage has constant
10 dimensions and the boundaries of the passage are
11 free of obstructions so that the fluid moves along
12 the passage without hindrance.

13
14 The passage typically comprises portions with axial
15 and transaxial components, so that the length of the
16 passage is greater than the length of the apparatus.

17
18 The transaxial components of the passage typically
19 cause the path of fluid flowing through the
20 apparatus to deviate from its former axial path
21 through the conduit prior to flowing through the
22 apparatus, thereby decelerating the fluid.

23
24 Preferably, the decelerating means further comprises
25 at least one spiral passage defined by the at least
26 one body member.

27
28 The angle of the spiral portion of the passage is
29 typically more than 60 degrees relative to the
30 conduit axis, preferably between 70 and 80 degrees
31 and most preferably around 75 degrees.

32

1 Preferably, the passage is uni-directional in the
2 axial direction, so that in use, when fluid is
3 flowing from the top to the bottom of the internal
4 passage, no part of the passage would direct fluid
5 up the apparatus.

6
7 Uni-directional embodiments have the advantage over
8 other designs which include passages having
9 upwardly-inclined portions and corresponding
10 troughs, in which any suspension would be inclined
11 to settle and block the passage.

12
13 Such uni-directional embodiments include those
14 having a spiral passage; the continual slope of the
15 spiral passage ensures that gravity can assist the
16 flow of fluid through the passage. Embodiments
17 incorporating the spiral design have the advantage
18 that any suspended particles carried by the fluid
19 will not settle in the passage and block the
20 passage.

21
22 Optionally, the passage includes at least two
23 portions spiralling in opposite directions to each
24 other. Optionally, the spiral passage includes at
25 least two of said portions and preferably oppositely
26 directed spiralling portions are positioned adjacent
27 one another.

28
29 Preferably, the passage includes two or more of said
30 portions and most preferably, the passage is formed
31 so that fluid travelling through a first portion
32 will flow in a clockwise direction through the

1 spiralling parts of that portion, and fluid
2 travelling through a second, neighbouring portion
3 will flow in an anti-clockwise direction through its
4 spiralling portion, or vice versa.

5

6 Typically, the decelerating means induces turbulence
7 into the fluid to decelerate the fluid.

8

9 Optionally, the turbulence is wholly, mainly or
10 partly induced by a direction-altering means, which
11 changes the direction of fluid flowing in the
12 internal passage. Typically, the direction-altering
13 means comprises a cavity provided between first and
14 second oppositely directed spiral passage portions,
15 providing a space in which the fluid changes
16 direction between the first spiral direction and the
17 second spiral direction. The cavity is typically
18 formed in the at least one body member and may
19 comprise a connecting passage linking the spiral
20 passage portions; the connecting passage may include
21 axial portions and transaxial portions.

22

23 Whether turbulent or laminar flow results depends
24 (among other parameters) on the speed of the fluid
25 through the passage. Thus, in embodiments of the
26 invention which induce turbulence, the apparatus can
27 have a decelerating effect on some fluids but not on
28 others, depending on the speed of the fluid. The
29 turbulence will only have a significant effect upon
30 fast flowing fluids and slow flowing fluids will not
31 be appreciably slowed.

32

1 However, simple embodiments of the invention, which
2 may comprise a member forming a simple spiral
3 passage or an alternative form of passage inclined
4 relative to the conduit axis, can optionally
5 decelerate fluids without any inducing any
6 significant turbulent effect.

7

8 Optionally, the spiral passage is tightly wound, so
9 that the spiral passage is longer than the conduit
10 in which it is positioned, and preferably
11 considerably longer. The angle of the spiral
12 passage in these tightly wound embodiments can be
13 between 75 degrees and 90 degrees to the conduit
14 axis. Such embodiments can cause fluids to be
15 decelerated due to forcing the fluids to continually
16 change direction in the (in use) horizontal plane
17 orthogonal to the axis. As the fluids travel in the
18 circular plane, they will typically collide with the
19 outer wall of the conduit, or any sleeve or shroud
20 surrounding the passage, and they will be
21 decelerated by friction between the fluids and that
22 interface. This can be in addition, or instead of,
23 any turbulent effect.

24

25 As explained above, embodiments including a spiral
26 passage have the advantage that gravity assists the
27 flow of fluids along the passage and that any
28 suspension in the fluids is prevented from settling
29 out, due to the continuing slope of the passage.

30

31 Optionally, the body members connect by interlocking
32 means, which may include tongues and grooves.

1

2 Optionally, the at least one body member is cemented
3 or otherwise fitted inside the casing or liner
4 string.

5

6 Typically, the apparatus is used in conjunction with
7 equipment, such as a shoe and/or a float collar, at
8 least one of which is provided with a valve
9 (typically a one-way valve). Preferably, the cross-
10 sectional area of the flow path through the passage
11 is greater than the cross-sectional area of the flow
12 path through the valve.

13

14 If the valve is provided in the float collar, and in
15 use, the float collar is located above the
16 apparatus, then this prevents the apparatus from
17 having a choke effect on any fluids passing through
18 it. As the area of the passage is greater than that
19 of the valve, the passage does not create a bigger
20 restriction to the flow of fluid than has already
21 been created by the valve and the fluid is not
22 "choked" by the passage.

23

24 Thus, in such embodiments, the rate of fluid leaving
25 the shoe and the deceleration of the fluid is not
26 limited by the cross-section of the passage, only by
27 the amount of turbulence or other decelerating
28 effect created by the apparatus.

29

30 Optionally, the apparatus includes at least one
31 collar attached to an end (preferably the lower end)
32 of the casing or liner string, the collar having

1 screw threads for attachment to further sections of
2 casing or liner.

3

4 The collar can replace the shoe at the (in use)
5 lower end of the apparatus. The collar may couple
6 the casing or liner tubular within which the
7 apparatus is inserted to further casing or other
8 equipment, in the case that another piece of
9 equipment is required directly above the shoe.

10

11 A conventional coupling is typically used to attach
12 the (in use) upper end of the casing or liner
13 tubular within which the apparatus is located to the
14 rest of the casing or liner string.

15

16 Preferably, the apparatus comprises an anti-rotation
17 means to prevent relative rotation of the body
18 members and thus the passage and the shoe.

19 Typically, the anti-rotation means includes a
20 device, which may be a sub, shaped to engage a bore
21 provided in the shoe. Preferably, an axial locking
22 means is provided to prevent axial separation of the
23 device and the shoe. Preferably, the axial locking
24 means comprises a latch provided on one of the
25 device and the shoe, and a groove (to engage the
26 latch) provided on the other of the device and the
27 shoe. Most preferably, the locking means comprises
28 a circlip provided on the device which is adapted to
29 engage a groove in the shoe to prevent axial
30 separation of the device and the shoe. Preferably,
31 the anti-rotation means comprises a tapered edge
32 provided on one of the device and the shoe and a

1 correspondingly shaped groove provided on the other
2 of the device and the shoe. Typically, the tapered
3 edge is provided on the device and the groove is
4 provided in the shoe. Typically, the anti-rotation
5 means prevents relative rotation of the at least one
6 body member and the shoe once the axial locking
7 means has engaged.

8

9 The anti-rotation means is useful to help prevent or
10 restrict the rotation of the at least one body
11 member and thus the passage when the at least one
12 body member is drilled through. Rotation of the
13 passage would be disadvantageous as rotation of the
14 drill bit could rotate the passage, if it is not
15 firmly cemented to the casing, instead of drilling
16 through the passage.

17

18 Optionally, the apparatus further comprises an outer
19 protection means, which may be a shroud. Typically,
20 the outer protection means is provided with
21 apertures in the side wall thereof.

22

23 According to a second aspect of the present
24 invention there is provided a control assembly,
25 including:

26 control apparatus for controlling the flow of
27 fluid into a borehole through a conduit, the
28 apparatus comprising a decelerating means adapted to
29 be positioned within the conduit for slowing down
30 the flow of fluid through the conduit, the
31 decelerating means comprising a passage in the
32 apparatus;

1 a conduit in which the control apparatus is
2 located; and

3 a valve located in the conduit above the
4 apparatus;

5 wherein the cross-sectional area of the passage
6 in the apparatus is greater than the cross-sectional
7 area of the valve.

8

9 Preferably, the valve is located in a float collar.

10

11 According to a third aspect of the present invention
12 there is provided a method of controlling the
13 passage of fluid through a conduit located in a
14 borehole, including the step of decelerating the
15 fluid.

16

17 Optionally, the fluid is decelerated by being passed
18 through a decelerating means located inside the
19 conduit, the decelerating means being adapted to
20 decelerate the fluid passing through the conduit.

21

22 Preferably, the decelerating means is inserted into
23 the conduit prior to running in the conduit into the
24 borehole.

25

26 Optionally, the deceleration is caused by the fluid
27 being forced to change direction. Optionally, the
28 method includes the step of causing the fluid to
29 deviate from the conduit into a passage which is
30 inclined relative to the conduit axis. Some, or
31 all, of the decelerating effect could be caused by

1 friction as fluid travels along a passage in the
2 apparatus.

3
4 Optionally, the fluid travels in a direction having
5 a circular component, which is typically in the (in
6 use) horizontal plane orthogonal to the axial
7 direction.

8
9 Typically, the fluid is decelerated by causing it to
10 travel through a passage, which may be a spiral
11 passage, defined by the decelerating means. In use,
12 the inclination of the spiral passage relative to
13 the vertical enables gravity to aid the motion of
14 the fluid through the passage, and means that any
15 particles suspended in the fluids are unlikely to
16 settle out in the passage to block the passage. The
17 spiral may be tight, so that fluid will travel
18 through a large distance in a small axial space.

19
20 Optionally, the fluid is decelerated by induction of
21 turbulence into the fluid. This may be achieved by
22 passing the fluid through a spiral passage including
23 portions spiralling in opposite directions. In such
24 embodiments, the turbulence may be induced in a
25 connection region between the portions where fluid
26 spiralling in one direction has to change direction
27 and spiral in the opposite direction.

28
29 Typically, the spiral passage includes a plurality
30 of oppositely directed spiralling portions
31 positioned in series and the fluid passes through a

1 plurality of connection regions as it flows through
2 the conduit.

3

4 Optionally, the amount of turbulence induced is
5 dependent on the speed of the fluid flow, and the
6 turbulence induced for slowly flowing fluids may be
7 zero or negligible.

8

9 Typically, a float collar having a valve is provided
10 in the conduit above the inclined passage, the
11 passage having a greater cross-sectional area than
12 the cross-sectional area of the valve so that the
13 fluid flows without restriction into the passage.

14

15 Typically, a shoe is attached to one end of the
16 conduit, the shoe having a fluid outlet, and fluid
17 is pumped or passed through the conduit and enters
18 the borehole by the fluid outlet.

19

20 Optionally, the inclined passage is defined by at
21 least one body member having formations thereon and
22 a shroud having apertures in its surface is provided
23 around the body member, and the method includes the
24 step of passing cement through the passage, some of
25 which exits the passage via the apertures to cement
26 the body member to the conduit.

27

28 An embodiment of the invention will now be described
29 by way of example only and with reference to the
30 following drawings, in which:-

31 Fig 1 shows a side view with interior detail of
32 two cement tools stacked on top of each other

1 and inserted in a downhole assembly between a
2 shoe and a casing string;
3 Fig 2 shows a side view with interior detail of
4 the shoe of Fig 1;
5 Fig 3 shows a perspective view of a connector
6 sub of Fig 1;
7 Fig 4 shows a side view with interior detail of
8 a collar which can be used with the tool of Fig
9 1;
10 Fig 5 shows a side view of a first tool
11 portion;
12 Fig 6 shows a side view of a second tool
13 portion;
14 Fig 7 shows a plan view of the rear (right
15 hand) end of the second tool portion of Fig 6,
16 rotated through 180°;
17 Fig 8 shows a plan view of the front (left
18 hand) end of the first tool portion of Fig 5;
19 Fig 9 shows a side view with some interior
20 detail exposed of one of the cement tools of
21 Fig 1;
22 Fig 10 shows a schematic diagram of the
23 apparatus assembled in a borehole, with cement
24 forcing the drilling mud through the apparatus;
25 Fig 11 shows a schematic diagram of the
26 apparatus with displacement fluid forcing the
27 cement through the apparatus;
28 Fig 12 shows a side view with interior detail
29 of an alternative embodiment of the invention,
30 including a tightly-wound spiral passage;
31 Fig 13 shows a schematic diagram of the Fig 12
32 embodiment of the invention located in a casing

1 string between a float collar and a float shoe;
2 and

3 Fig 14 shows a schematic diagram of an
4 alternative arrangement to Fig 13, having a
5 spiral passage spiralling in one direction
6 only.

7
8 Fig 1 shows apparatus in accordance with the present
9 invention comprising a first cement tool 10 and a
10 second cement tool 20 coupled together. Each tool
11 10, 20 is made up of a first body member 30 having a
12 left hand spiral portion and a second body member 40
13 having a right hand spiral portion, shown in Figs 5,
14 6, 7 and 8. It will, however, be appreciated that
15 the left and right hand spiral portions may be
16 swapped with one another.

17
18 The cement tools 10, 20 are located inside a length
19 of casing 60, which has standard screw thread
20 connections on each end. The upper end of casing 60
21 is connected to a casing coupling 12 which is
22 attached to the rest of the casing string (not
23 shown). It is not necessary for the tools 10, 20 to
24 be located inside casing 60; the tools 10, 20 may be
25 located inside any conduit which is inserted into
26 the borehole, such as drillpipe, tubing, coil tubing
27 or liner. The cement tools 10, 20, do not
28 necessarily extend all the way up the length of
29 casing 60 as shown in Fig 1; the cement tools 10, 20
30 typically only extend approximately halfway up the
31 length of casing 60.

32

1 Each body member 30, 40 has a central column 31, 41
2 with a spiral protrusion 34, 44 extending therefrom.
3 The radially outer edge of the spiral protrusions
4 34, 44 extends substantially to the inner wall of
5 the casing 60. Thus, a spiral passage 36, 46 is
6 formed between the surfaces of the spiral protrusion
7 34, 44, the central column 31, 41 and the inner
8 surface of the casing 60.

9
10 The body members 30, 40 are connected together by
11 inter-engaging tongues and grooves. Each body
12 member 30, 40 has a dove tail or tongue 32 at one
13 end (here, the upper end with respect to the
14 borehole) and a groove 42 in the opposite end.
15 However, in some embodiments, the positions of the
16 tongues 32 and the grooves 42 are reversed. Each
17 tongue 32 is dimensioned so that it is a tolerance
18 fit with its respective groove 42 so that the
19 portions 30, 40, will not become accidentally
20 disconnected in the borehole.

21
22 The cement tools 10, 20 are connected together in
23 the same way as the body members 30, 40; i.e. by
24 connecting the groove 42 of the second body member
25 40 of the first tool 10 with the tongue 32 of the
26 first body member 30 of the second tool 20. A
27 connecting passage 86 joins the spiral passages 36,
28 46 of the body members 30, 40 together, as best
29 shown in Fig 9. The connecting passage 86 is
30 preferably cylindrical, having a first axial portion
31 88 which extends from the (in use lower) end of
32 spiral passage 46, a second axial portion 89 which

1 extends from the (in use upper) end of the spiral
2 passage 36 and a third transaxial portion 86A, 86B
3 being a passage travelling through, and across the
4 axis of, the cement tool 10, 20, connecting the
5 first and second axial portions together. The first
6 88 and second 89 axial passage portions are formed
7 from a pair of off-centre axially arranged
8 cylindrical bores formed respectively through the
9 members 40, 30 and the third transaxial passage
10 portion 86 is formed from a transaxially arranged
11 cylindrical bore 86 formed through the body members
12 30, 40 when joined together, so that the transaxial
13 bore 86 spans the join between the body members 30,
14 40.

15
16 In some embodiments, transaxial passage 86 may be
17 inclined relative to the (in use) horizontal plane,
18 so as to continue the inclined path of spiral
19 passages 36, 46.

20
21 Fluid flowing through the cement tools 10, 20 will
22 be decelerated by being forced to change from axial
23 to spiral flow.

24
25 The lower end of casing 60 is connected to a shoe 14
26 by means of standard screw threads. The cement tool
27 10 is connected inside the shoe 14 by an anti-
28 rotation connector sub 16 (shown in Fig 3). The
29 connector sub 16 has a groove 42 which engages the
30 tongue 32 of the lower end of the first cement tool,
31 10. The connector sub 16 has a front portion 54 and
32 a rear portion 56. Both portions 54, 56 are

1 cylindrical but portion 56 has a larger diameter.
2 The lower end of portion 56 tapers to a point to
3 provide a tapered end 58. A circlip 62 is disposed
4 in a groove in the front portion 54.

5

6 The shoe 14 has an inner bore shaped to co-operate
7 with the outside surface of the connector sub 16.
8 The inner bore has a narrow portion 68 with a groove
9 64 for engagement of the circlip 62. The inner bore
10 of the shoe 14 also has a wider portion 69 having a
11 V-shaped receiving surface 70 corresponding to the
12 tapered end 58 to receive the tapered end 58.

13

14 The connector sub 16 is inserted into the shoe 14
15 and, once the circlip 62 is aligned with the groove
16 64 in the inner bore of the shoe 14, the circlip 62
17 expands into the groove 64. This prevents further
18 axial movement between the shoe 14 and the connector
19 16 (and hence the tools 10, 20 and the rest of the
20 apparatus).

21

22 The connector sub 16 can be inserted at any angle,
23 as it will align itself due to the tapered end 58
24 mating with the V-shaped receiving surface 70. Once
25 the circlip 62 is engaged, the tapered end 58 cannot
26 escape from the V-shaped receiving surface 70 as the
27 axial movement needed to do this is prevented by the
28 engaged circlip 62. Furthermore, the connector sub
29 cannot rotate relative to the shoe 14 due to the
30 mating of the tapered end 58 and the V-shaped
31 receiving surface 70. Therefore, the shoe 14 is

1 fixed relative to the cement tools 10, 20, both
2 rotationally and axially.

3

4 The shoe 14 has a nose 50 having outlet ports 52 to
5 allow fluids to pass through the shoe 14 into the
6 annulus between the casing and the borehole (not
7 shown). The shoe 14 also typically has a one-way
8 valve 55, to prevent fluids from flowing back into
9 the casing string.

10

11 The apparatus is typically used in conjunction with
12 a float collar, as shown in Figs 10 and 11. In
13 these figures, casing 60 (in which cement tools 10,
14 20 are located) is shown coupled beneath a float
15 collar 96. Float collar 96 can be a standard float
16 collar which is commercially available; such float
17 collars usually include a valve 105, which is
18 typically a one-way valve. For safe operation of
19 the equipment, a valve must be provided in at least
20 one of the float collar 96 and the shoe 14.

21

22 The cross-sectional areas of the respective passages
23 36, 46 inside the tools 10, 20 are preferably
24 greater than the cross-sectional area of the valve
25 105. This means that the fluid flow rate is not
26 limited by the cross-sectional area of the passages
27 36, 46. The fluid flow rate is only limited by the
28 amount of turbulence created inside the tools 10,
29 20. Therefore the cement tools 10, 20 do not
30 "choke" the fluid, as they do not restrict the
31 cross-sectional area through which it flows.

32

1 Fig 4 shows a collar 80 which can be attached to the
2 cement tool 10, instead of the shoe 14. The collar
3 80 is typically used in the cases where it is not
4 desired to connect the tools 10, 20 directly to the
5 shoe 14, e.g. if another tool is required to be
6 inserted above the shoe 14. However, it will also
7 be appreciated that the cement tools 10, 20 could be
8 placed at any suitable position in the conduit by
9 any suitable locating device such as adhesives etc.
10 or even by providing the outer diameters of the
11 cement tools 10, 20 as a clearance fit with the
12 inner diameter of the conduit. Each end of the
13 collar 80 is screw threaded for engagement with
14 casing 60 and for engagement with further casing
15 (not shown). The collar 80 has an inner bore
16 similar to that of the shoe 14 for engagement with
17 the connector sub 58. The inner bore has a narrow
18 portion 68 with a groove 64 for engagement of the
19 circlip 62 and a wide portion 69, having a tapered
20 circumference 70 corresponding to the tapered end
21 58. The collar 80 may be used to position the tools
22 10, 20 above the shoe track 93 (the shoe track is
23 shown in Figs 10 and 11). (The shoe track 93 is a
24 common term in the industry to designate the
25 combination of a shoe, one or two joints of casing
26 and a float collar.)

27

28 Fig 9 shows the tool 10 having a shroud 82 around
29 the exterior, which could be formed from an easily
30 drillable material. The shroud 82 has apertures 84
31 formed in its side wall. The apertures 84 are

1 typically distributed throughout the surface of the
2 shroud 82.

3

4 The shoe 14, the tools 10, 20, the connector sub 16,
5 any collar 80 and any plugs used with the apparatus
6 are preferably made from materials which can be
7 drilled through, such as a plastic or aluminium.
8 The tools 10, 20 and connector sub 16 are preferably
9 made out of a thermoplastic.

10

11 In use, the shoe 14, connector sub 16, tools 10, 20,
12 casing 60 and casing coupling 12 are connected to
13 form the assembly shown in Fig 1 by engaging screw
14 threads, tongues and grooves as described above.
15 The assembly is then run into the borehole and
16 drilling mud is pumped down through the casing
17 string. When the assembly reaches the required
18 depth, the casing is cemented in place. This is
19 done by pumping cement down through the casing
20 string. The cement is pumped on top of the drilling
21 mud already in the casing string, and displaces the
22 drilling mud, accelerating the mud down through the
23 casing string and the tools 10, 20.

24

25 The cement may be pumped directly on top of the
26 drilling mud, in which case it could be advantageous
27 to start with a low density cement slurry and to
28 gradually build up the density. Cement additives
29 (commercially available) have been developed to
30 control the density of the cement slurry. The
31 density can be lowered by adding an additive which
32 has a low specific gravity, or which allows large

1 quantities of water (which is lighter weight than
2 cement) to be added to the cement, or a combination
3 of both. The lead slurry should therefore be the
4 lightest; typically around 10 lb/gallon, followed by
5 an intermediate slurry of around 11.5 lb/gallon, and
6 a tail slurry of 15 lb/gallon.

7

8 In this way, full density cement is not directly on
9 top of the drilling mud, and this reduces the
10 probability of the cement falling through the mud.
11 The decelerating action of the tools 10, 20, which
12 will be detailed subsequently, also reduces the
13 likelihood that the cement will fall through the
14 mud.

15

16 Alternatively, as shown in Fig 10, a plug 90 could
17 be positioned between the drilling mud 94 and the
18 cement 92. The plug 90 typically has a sheer
19 section 91 which breaks on the application of a
20 threshold pressure. In the case where the tools 10,
21 20 are located directly on top of the shoe 14, the
22 plug 90 lands on top of the float collar 96. Fig 11
23 shows the plug 90 landed and sheared by the pressure
24 of the cement 92 above it. The float collar 96
25 typically has an anti-rotation device (not shown),
26 such as saw tooth protrusions, to engage the plug 90
27 and to prevent rotation of the plug 90 when it is
28 subsequently drilled through.

29

30 The Fig 10 embodiment also shows the casing 60
31 (which contains the cement tools 10, 20) and a
32 following casing string 61 having commercially

1 available centralisers 98 to hold the casing 60 and
2 the casing string 61 in the centre of the borehole
3 95.

4

5 In the case (not shown) where the tools 10, 20 are
6 located above the shoe track 93 such that the tools
7 10, 20 would be located in the casing string 61, a
8 landing device (not shown) is typically provided to
9 land the plug 90. The landing device would
10 typically have an anti-rotation device to prevent
11 rotation of the plug, as explained above.

12

13 Before the cement puts pressure on the drilling mud,
14 the drilling mud flows slowly enough through the
15 tools 10, 20 for the flow to be laminar. The flow
16 of the drilling mud is not choked by the apparatus,
17 because the cross-sectional areas of passages 36, 46
18 are greater than the cross-sectional area of the
19 valve 105 in the float collar 96. Thus, the tools
20 10, 20 do not restrict the flow of the drilling mud
21 before the cement is introduced into the casing
22 string; the only restriction on the flow of the
23 drilling mud is the size of the valve 105.

24

25 However, when the mud is accelerated by the cement,
26 the velocity of the mud is increased sufficiently
27 for the drilling mud to become turbulent. As the
28 drilling mud passes from the right-hand spiral
29 portion 40 to the left-hand spiral portion 30, the
30 drilling mud is forced to spiral in the opposite
31 direction. Anticlockwise spiralling mud meets
32 clockwise spiralling mud in the passage 86 between

1 the portions 30, 40 such that eddy currents build up
2 and the mud in the passage becomes turbulent. The
3 turbulence restricts the flow of the mud through the
4 tools 10, 20. Thus, the velocity of the mud which
5 leaves the shoe and flows up the annulus between the
6 casing and the formation is reduced, thereby
7 exerting a reduced pressure on the formation and
8 reducing the probability of the formation breaking
9 down.

10

11 When the cement reaches the tools 10, 20, some of
12 the cement flows through the apertures 84, which
13 serves to cement the tools 10, 20 to the casing 60.

14

15 Cement is continued to be pumped through the casing
16 string until all the drilling mud 94 has been
17 expelled from the shoe 14 and the cement 92 now
18 fills the annulus between the casing string 61 and
19 the borehole 95. A plug 102 (see Fig 11) is
20 typically used to act as a separator between the
21 cement 92 and a displacement fluid 100 (e.g. more
22 drilling mud) used to propel the cement 92
23 downwards. Typically, this plug 102 lands on the
24 float collar 96 (or the landing device, if the tools
25 10, 20 are located above the float collar 96), on
26 top of any previous plug 90. Thus, when the cement
27 92 sets, in addition to filling the annulus, it will
28 also fill all of the apparatus below the plug,
29 including the tools 10, 20.
30 If deeper drilling is required, any plugs, the tools
31 10, 20, any collar 80 and the shoe 14 are drilled
32 through.

1
2 Modifications and improvements can be made without
3 departing from the scope of the invention. For
4 example, more or fewer tools 10, 20 may be used in
5 combination. The plastic or aluminium shroud 82 and
6 the anti-rotation connector sub 16 are not essential
7 elements of the invention. For instance, the tools
8 10, 20 could be cemented into the casing 60, or
9 otherwise fixed to the casing 60 or the casing
10 coupling 12; thus obviating the need for the anti-
11 rotation connector sub 16.

12
13 Also, left-hand and right-hand spiral portions 30,
14 40 need not be positioned alternately; two portions
15 30 could be followed by two portions 40. The tool
16 could optionally comprise only one spiral portion,
17 or a combination of uni-directional spiral portions.
18 In further alternative embodiments, the spiral
19 portions 30, 40 could be replaced by a combination
20 of straight axially arranged portions (not shown)
21 and circumferentially arranged portions (not shown)
22 such that the fluid would flow around a
23 circumferential portion at one height and then flows
24 down the straight axially arranged portion to the
25 next lower circumferential portion and so on.

26
27 Furthermore the spiral portions 30, 40 need not be
28 attached by tongues and grooves; other attachment
29 means such as screw threads could be provided.
30 The shoe 14 could be any type of shoe such as a
31 reamer shoe, a guide shoe or a float shoe.

32

1 The anti-rotation sub 16 is not an essential feature
2 of the invention. In some embodiments, it is not
3 necessary, e.g. the cement tools 10, 20 can be
4 cemented, jammed or secured in any other way to the
5 inside of the casing or other conduit so as to
6 prevent rotation.

7

8 In the case where the cement tools 10, 20 are
9 located inside drillpipe, neither the shoe 14 nor
10 the collar 80 would be necessary. The drillpipe
11 could be hung off (i.e. from a casing string) in
12 such a way as to prevent rotation of the drillpipe.
13 The cement tools 10, 20 could be dimensioned to be a
14 clearance fit inside the drillpipe, to jam the tools
15 10, 20 inside the drillpipe to prevent relative
16 rotation therebetween.

17

18 The passage 86 between spiral portions 30 and 40
19 could include a chamber wider than the rest of the
20 passage in which the streams of oppositely flowing
21 fluid could meet and interact.

22

23 A further modification is shown in Fig 12, which
24 shows an modified cement tool 110 inserted inside a
25 casing length 122. Casing coupling 12 is also
26 shown; casing coupling 12 is the same as that shown
27 in Fig 1, and therefore the same reference number
28 has been used.

29

30 Like the cement tools 10, 20 of the Fig 1
31 embodiment, cement tool 110 has a central column 112
32 with a spiral protrusion 114 extending therefrom.

1 Spiral protrusions 114 extend substantially to the
2 inner wall of the casing 122 and define a spiral
3 passage 116 between the surfaces of the spiral
4 protrusion 114, the central column 112 and the inner
5 surface of casing 122. The spiral is typically
6 tightly wound, so that spiral passage 116 is longer
7 than the axial length of cement tool 110. Spiral
8 passage 116 spirals clockwise when viewed from the
9 (in use) upper end of cement tool 110.

10

11 As in the Fig 1 embodiment, the spiral passage 116
12 permits gravity to aid the flow of fluids along the
13 passage, and reduces the chance of any suspended
14 particles carried by the fluid settling out and
15 blocking the passage.

16

17 It can be beneficial if the cross-sectional area of
18 spiral passage 116 is greater than the cross-
19 sectional area of a typical float collar valve. In
20 such embodiments, the passage 116 does not limit or
21 choke the flow of fluids when used in combination
22 with a float collar having a valve. However,
23 alternative embodiments of the invention can have a
24 passage with a smaller cross-sectional area than
25 that of a float collar valve.

26

27 Although only one cement tool 110 is shown in Fig
28 12, it will be appreciated that this could be
29 attached to one or more further cement tools, e.g.
30 by interlocking tongues and grooves, as shown in the
31 Fig 1 embodiment. The further cement tool may have

1 a passage which spirals in a clockwise or
2 anticlockwise direction.

3

4 Fig 13 shows a schematic diagram of an assembly
5 including two types of cement tool 110, 140. In
6 this embodiment, two lengths of casing 122, 120 are
7 connected together between float collar 96 and shoe
8 14. However, the invention is not limited to use in
9 conjunction with a either a float collar or shoe.

10

11 Cement tool 110 is the one shown in detail in Fig
12 12. Cement tool 140 is similar to cement tool 110,
13 also having spiral protrusions 114 which define a
14 spiral passage 116. However, the direction of
15 spiral passage in cement tool 140 is reversed; this
16 passage is spiralling anticlockwise when viewed from
17 the (in use) upper end of the cement tool.

18

19 A first pair of cement tools 110, 140 are connected
20 together; these are also connected to a second pair
21 of cement tools 110, 140. In this embodiment, each
22 cement tool 110, 140 is half as long as a length of
23 casing, so that the two pairs of cement tools 110,
24 140 fill both casing lengths 120, 122. In this
25 schematic diagram, diagonal lines indicate the
26 spiral protrusions 114 and the direction of spiral,
27 but the full details of the cement tools 110, 140
28 are not shown.

29

30 However, it will be appreciated that the length of
31 each cement tool 110 is not important, and a greater
32 number of shorter cement tools, or a smaller number

1 of longer cement tools could equally be used. A yet
2 alternative arrangement is shown in schematic form
3 in Fig 14, wherein a single, longer cement tool 150
4 is located inside casing length 120. Cement tool
5 150 is of the same form as cement tool 110 shown in
6 detail in Fig 12, only longer. Thus, this
7 embodiment causes fluid to spiral in one direction
8 only. In this embodiment, no cement tool is located
9 inside casing 122, which is empty.

10

11 As with the Fig 1 embodiment, a shroud (see Fig 9)
12 can optionally be provided around cement tool 110,
13 although this detail is not shown in Figs 12 to 14.

14

15 In the embodiments of Figs 12 to 14, spiral passage
16 116 between spiral protrusions 114 is long and
17 tightly wound. Therefore, the total length of
18 spiral passage (i.e. made up of the combined lengths
19 of the passages 116 of all of the cement tools 110,
20 140 used) is considerably longer than (and may be
21 many times as long as) the length of casing in which
22 the cement tools 110, 140 are located.

23

24 In use, cement tools 110, 140 are fitted together
25 and assembled inside the casing lengths 122, 120 as
26 required between float shoe 14 and float collar 96.
27 Cement is then pumped down the inside of the casing.
28 The details of this are the same as described above
29 with reference to the previous embodiment, e.g. the
30 first portion of cement is typically low density
31 cement slurry, and the density is then gradually
32 built up to full density to reduce the likelihood of

1 the cement "falling through" the drilling mud.
2 Alternatively or additionally, a plug with a sheer
3 section (such as plug 90 in Fig 10) can be used to
4 keep the cement and the drilling mud separate until
5 plug 90 lands on float collar 96.

6
7 The cement pushes the drilling mud through the
8 cement tools 110, 140. The drilling mud is forced
9 to continually change direction to follow the spiral
10 passage 116. The tighter the spiral, the greater
11 the decelerating effect. Friction with the inside
12 of the casing (or optional protective shroud) and
13 spiral protrusions 114 decelerates the drilling mud.
14 Thus, the embodiments shown in Figs 12 to 14 can
15 decelerate a fluid with or without any additional
16 deceleration caused by turbulence.

17
18 The drilling mud is propelled out of shoe 14 and up
19 the annulus between the outside of casing lengths
20 122, 120 and the borehole. However, as its speed
21 has been reduced by cement tools 110, 140, the
22 pressure on the formation is eased, rendering the
23 formation less likely to collapse.